JET PROPULSION LABORATORY **INTEROFFICE MEMORANDUM**
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TO: G. H. Blackwood

FROM: R. P. Korechoff

SUBJECT: Polarization analysis of SIM classic and Son of SIM designs

INTRODUCTION

In order to insure that light from the two arms of an interferometer will produce fringes, the effects of several reflections on the state of polarization must be tracked. Tracking the polarization can be accomplished by assuming a convention regarding the effect of a reflection on each state of polarization. We assume the following convention: (1) S-polarization states are unaffected by a reflection; (2) P-polarization states reflect like an arrow pointing in the direction of the electric field. It is not always the case that the incident polarization states are parallel (P) and perpendicular (S) to the plane of reflection. In those cases where the incident polarization vectors are not aligned with the plane of reflection it is necessary to project the incident polarization states into the S and P states for the given reflection. Note that the polarization arrow represents a vector and thus has magnitude and direction. Fringes of visibility unity (assuming a perfectly coherent source) are produced when the polarization vectors from the two arms of the interferometer agree in magnitude and direction.

The starlight optical train in the SIM classic may be grouped into four parts: (1) light collecting and beam alignment optics, (2) upper and lower switch yards, (3) delay line, and (4) beam combiner. The Son of SIM (SOS) designs have different light collecting and beam alignment optics but the same switch yards, delay line, and beam combiner as the SIM classic design. Therefore, we need only compare the polarization states leaving the upper switch yard for the SIM classic and SOS designs. In the next section we analyze the SIM classic design and two competing SOS designs.

ANALYSIS

SIM Classic

Figure 1 shows the complete SIM classic starlight optical system. The optical paths for the two arms have mirror image symmetry. Using the reflection convention defined above we trace two polarization states arbitrarily labeled 1 and 2. The ray paths are identical up to the alignment mirrors (AM). At this point the polarization vectors are no longer properly aligned with the plane of reflection. To properly orient the polarization vectors we have to rotate the vectors in one arm by $+\phi$ around the z axis and by $-\phi$ in the other arm. The new polarization vectors are denote by single and double primes are given quantitatively by

$$1' = 1 \cos\phi + 2 \sin\phi \qquad (1a)$$
$$2' = -1 \sin\phi + 2 \cos\phi \qquad (1b)$$

$$1'' = 1 \cos\phi - 2 \sin\phi \qquad (2a)$$
$$2'' = 1 \sin\phi + 2 \cos\phi \qquad (2b)$$

where 1 and 2 are the magnitudes of the two polarization states.

Tracking the polarization vectors from the alignment mirrors through the beamsplitter we see that both the 1 and 2 polarization vectors line up from both arms. However, in general the magnitudes are not equal as shown in Eqs. (1) and (2). The magnitude inequality of the polarization vectors reduces the fringe visibility.

The polarization vector magnitudes can be corrected by making the optical paths of the two interferometer arms in Fig. 1 congruent. That is, one can be superimposed exactly over the other. This requires reorienting the static delay. Another solution is to keep the mirror image symmetry, make ϕ zero, and send the beam in the z direction before directing it toward the upper switch yard. Finally, we note that if the polarization vector directions and magnitudes agree after they leaving the upper switch yard, they will agree when combined at the beamsplitter.

SOS

The starlight optical system for the baseline SOS design is illustrated up through the upper switch yard in Fig. 2. We have traced two incident polarization vectors as we did for the SIM classic design. The reflections at mirrors MA and MB produce changes in the magnitudes of the two vectors; the new magnitudes are indicated by a superscript prime. We don't need to determine the exact magnitudes of the vectors because they are the same in both arms. Hence, the vectors in both arms are labeled with a single prime. The rest of the analysis shows that the polarization vectors from the two arms are equal in magnitude and direction upon leaving the upper switch yard.

Figure 3 shows a modification to the baseline SOS design with the introduction of mirror MA'. The analysis demonstrates that this modified SOS design also produces polarization states from the two arms that agree in magnitude and direction upon leaving the upper switch yard.

CONCLUSIONS

The above analysis shows that the SIM classic design produces final polarization states from the two arms of the interferometer that agree in direction but, in general, not in magnitude. This has the effect of reducing the fringe visibility. The analysis of the baseline and modified SOS designs demonstrate that the final polarization vectors from the two arms agree in magnitude and direction.

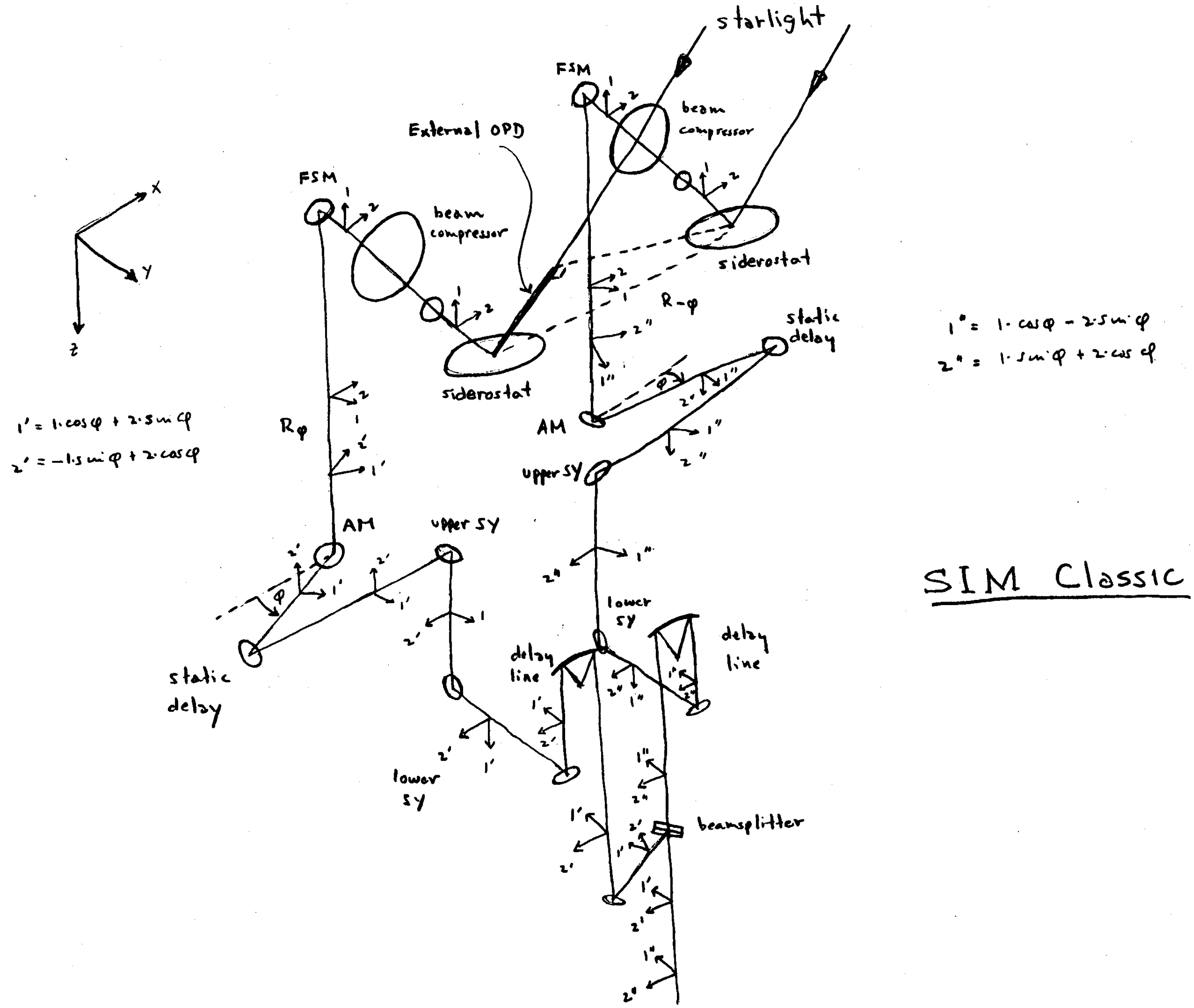
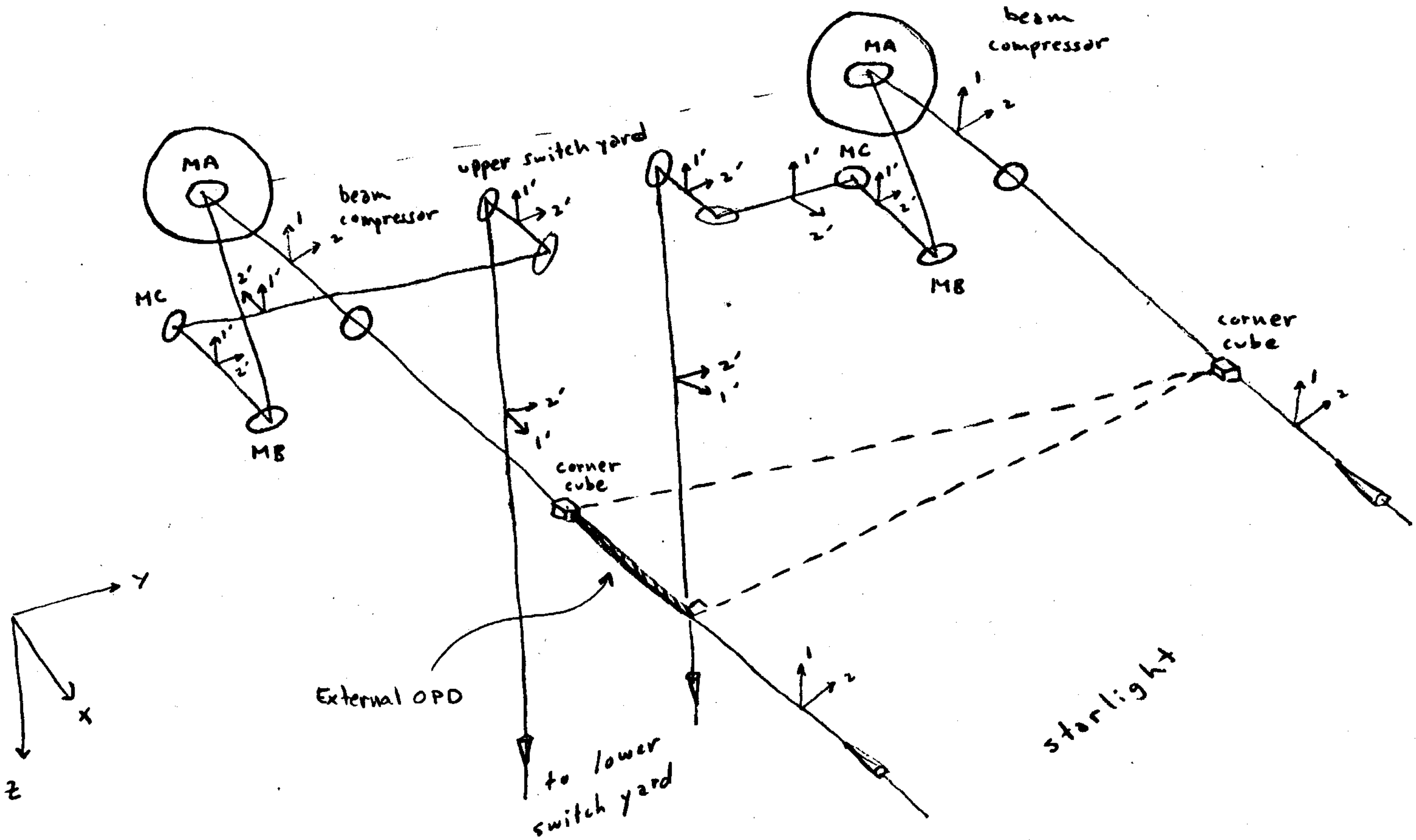

starlight
FSM
beam compressor
External OPD
siderostat
FSM
beam compressor
siderostat
R-φ
static delay
AM
upper SY
lower SY
delay line
delay line
Rφ
AM
upper SY
static delay
lower SY
beamsplitter
x
y
z
$1' = 1\cdot\cos\varphi + 2\cdot\sin\varphi$
$2' = -1\cdot\sin\varphi + 2\cdot\cos\varphi$
$1'' = 1\cdot\cos\varphi - 2\cdot\sin\varphi$
$2'' = 1\cdot\sin\varphi + 2\cdot\cos\varphi$
SIM Classic

Figure 1



SOS' - Baseline

Figure 2

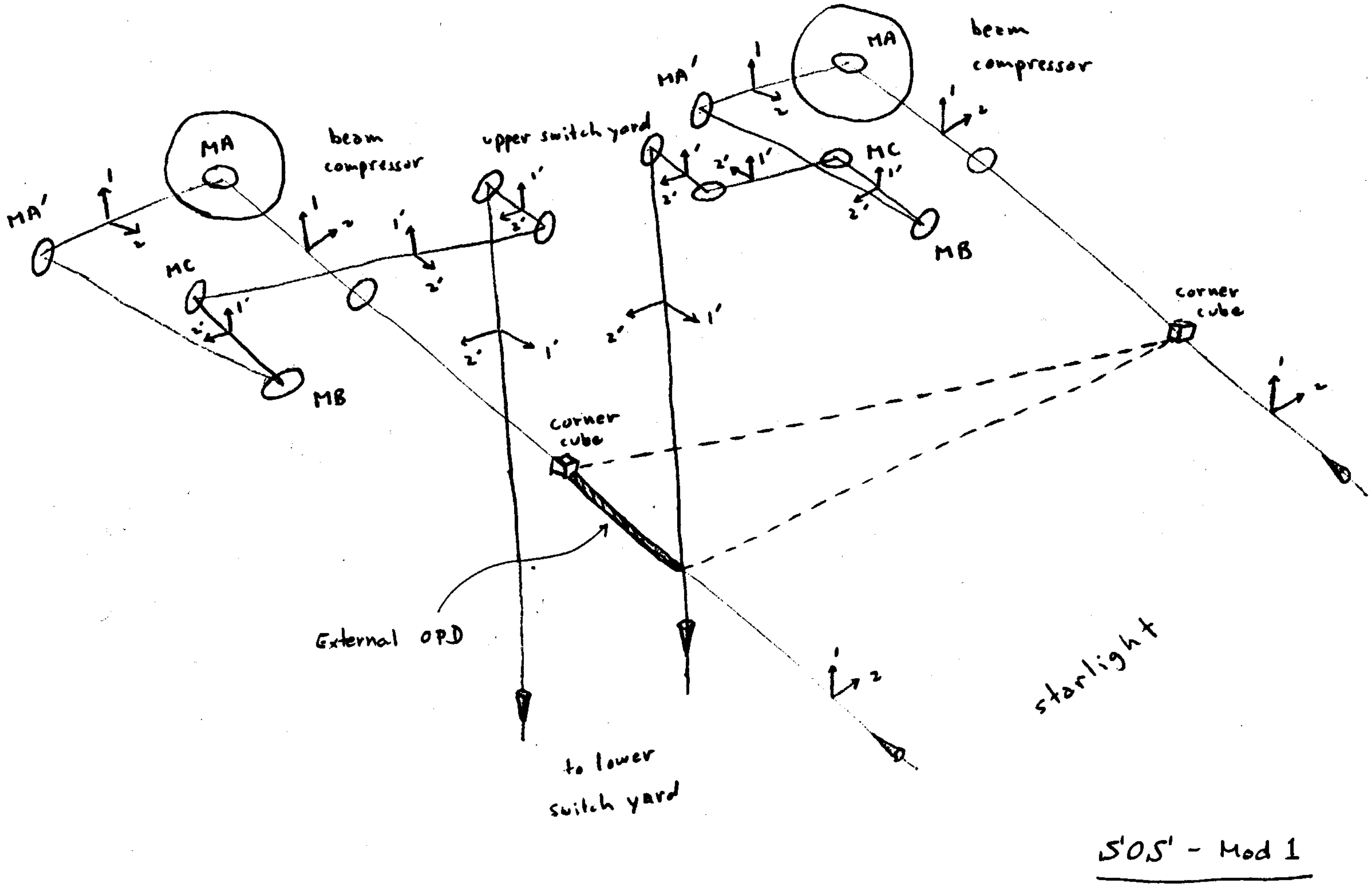

MA
MA'
beam
compressor
MC
MB
upper switch yard
MA
MA'
beam
compressor
MC
MB
corner
cube
corner
cube
External OPD
to lower
switch yard
starlight
SOS - Mod 1

Figure 3